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# Final Technical Report

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## Abstract

A special issue of the technical journal, *Earthquake Spectra,* titled "Seismic Hazard in Central and Eastern North America (CENA)" was released in July 2021 to showcase new developments in earthquake hazard and risk assessments relevant to Central and Eastern North America (CENA). This unique collection of papers marks a significant advancement in the documentation and understanding of hazard and risk of this stable continental region with rare but significant seismicity.

A substantial portion of the special issue features a selection of papers from the multi-year and multi-disciplinary research project Next Generation Attenuation Relationships for Central & Eastern North-America (NGA-East) Project, coordinated by the Pacific Earthquake Engineering Research Center (PEER). These papers describe different aspects and products of the NGA-East Project and summarize the new ground motion characterization model for the CENA region. The products of this research will influence the design and construction of countless facilities, from transportation and nuclear power infrastructure to commercial and residential buildings, for the next several decades as the models are adopted into building codes and design provisions.

Several CENA-relevant research projects and activities have taken place in addition to NGA-East. Thus, this special issue also contains papers related to analysis, modeling and implementation of seismic ground motions and hazard in CENA.

This collection of papers is intended for scientists and researchers in the hazard and risk modeling sector, as well as engineers and other professionals involved in the seismic design of buildings and infrastructure or in seismic risk studies in the CENA region or other similar stable continental regions around the globe.

## Introduction

A special issue of the technical journal, *Earthquake Spectra,* titled "Seismic Hazard in Central and Eastern North America (CENA)" was released by EERI in July 2021.

About EERI

The Earthquake Engineering Research Institute is the leading non-profit membership organization dedicated to understanding earthquake risk and increasing earthquake resilience in communities worldwide. Our diverse multidisciplinary membership includes researchers, practitioners, and students in engineering, geoscience, social science, architecture, planning, government, emergency management, public health, and policy making. EERI has been bringing people and disciplines together since 1948. More about EERI can be found at http://www.eeri.org.

About *Earthquake Spectra*

*Earthquake Spectra* is the professional peer-reviewed journal of EERI, currently published by SAGE. *Earthquake Spectra* serves as the publication of record for the development of earthquake engineering practice, earthquake codes and regulations, earthquake public policy, and earthquake investigation reports. The journal is published quarterly in both printed and online editions in February, May, August, and November, with additional special edition issues.

EERI established Earthquake Spectra with the purpose of improving the practice of earthquake hazards mitigation, preparedness, and recovery — serving the informational needs of the diverse professionals engaged in earthquake risk reduction: civil, geotechnical, mechanical, and structural engineers; geologists, seismologists, and other earth scientists; architects and city planners; public officials; social scientists; and researchers.

Special issues of *Earthquake Spectra* are highly valuable compendiums of new knowledge for the NEHRP community that are timely and help bridge the gap between research and practice. Special Issues of *Earthquake Spectra* are produced from time to time with the intent of informing the practitioner community in the U.S. on the latest research efforts that are at the stage of implementation.

About the PEER NGA-East Project

NGA-East was a multi-disciplinary research project coordinated by the Pacific Earthquake Engineering Research Center (PEER), with headquarters at the University of California, Berkeley. The objective of NGA-East was to develop a new ground motion characterization model for the Central and Eastern North-American (CENA) region. The GMC model consists of a set of new ground motion prediction equations (GMPEs) for median and standard deviation of ground motions (GMs) and their associated weights in the logic-trees for use in probabilistic seismic hazard analyses (PSHA). It provides the best estimate of the distribution of average horizontal ground motions on hardrock sites located up to 1,000 km from future earthquakes in the CENA region with moment magnitudes in the 4.0 to 8.0 range. More about NGA-East and PEER can be found at https://peer.berkeley.edu/research/nga-east

The project involved a large number of participating researchers from various organizations in academia, industry and government. The project was jointly sponsored by the U.S. Nuclear Regulatory Commission (NRC), the U.S. Department of Energy (DOE), the Electric Power Research Institute (EPRI) and the U.S. Geological Survey (USGS).

The NGA-East project was completed in December 2018 and involved a large number of participating researchers from organizations in academia, industry and government. The project resulted in several products, including the NGA-East ground motion database and multiple ground motion models. With the research project complete, there was a need to disseminate results and products widely to ensure that results are adopted into practice. This need led to the development of the *Earthquake Spectra* Special Issue.

## Seismic Hazard in Central and Eastern North America (CENA) Special Issue

Development

Upon grant acceptance, the project team (including EERI staff, Earthquake Spectra Editor-In-Chief, and Guest Editors Yousef Bozorgina and Christine Goulet) discussed specific research topics that were desired to showcase the results of NGA-East. These discussions led to the idea to expand the issue to include research from subsequent and parallel research projects beyond the scope of NGA-East, yet yielding important and relevant findings associated with the characterization of seismic hazard in the CENA region. As a result, the project team decided to invite submission of 7 papers relevant to NGA-East, and also release an open call for papers from the broader community.

Call for Papers

The Call for Papers was open from April 30 - July 15, 2020. It solicited papers related to simulated and empirical data, analyses and modeling ground motion, or any other relevant topic having a direct impact on the estimation of seismic hazard for CENA and other similar stable continental regions. The Call for Papers was advertised widely through various EERI and PEER communication channels, along with announcements to several partner organizations and outreach to various research groups familiar with NGA-East.

The Call for Papers resulted in the submission of 18 papers for review. Submitted papers were reviewed via the robust and thorough peer-review process utilized by *Earthquake Spectra*. Submitted papers underwent various revisions before final acceptance.

Production and Release

Upon acceptance, each of the 16 accepted papers were processed through the final production steps (copy editing, layout into the *Earthquake Spectra* format, and assignment of a unique Digital Object Indicator (DOI)) then individually released online once ready. The official release dates of each paper are listed below.

The entire Special Issue was published and announced as a complete online collection of papers in July 2021.

Table of Contents

The following papers were included in the final issue:

1. NGA-East Ground-Motion Characterization model part I: Summary of products and model development by Christine A Goulet, Yousef Bozorgnia, Nicolas Kuehn, Linda Al Atik, Robert R Youngs, Robert W Graves and Gail M Atkinson.

   *Release Date: July 13, 2021. https://doi.org/10.1177/87552930211018723*

2. NGA-East ground-motion characterization model Part II: Implementation and hazard implications by Robert R Youngs, Christine A Goulet, Yousef Bozorgnia, Nicolas Kuehn, Linda Al Atik, Robert W Graves and Gail M Atkinson

   *Release Date: June 6, 2021. https://doi.org/10.1177/87552930211007503*

3. PEER NGA-East database by Christine A Goulet, Tadahiro Kishida, Timothy D Ancheta, Chris H Cramer, Robert B Darragh, Walter J Silva, Youssef MA Hashash, Joseph Harmon, Grace A Parker, Jonathan P Stewart and Robert R Youngs

   *Release Date: July 13, 2021. https://doi.org/10.1177/87552930211015695*

4. The 2018 update of the US National Seismic Hazard Model: Ground motion models in the central and eastern US by Sanaz Rezaeian, Peter M Powers, Allison M Shumway, Mark D Petersen, Nicolas Luco, Arthur D Frankel, Morgan P Moschetti, Eric M Thompson and Daniel E McNamara

   *Release Date: March 19, 2021. https://doi.org/10.1177/8755293021993837*

5. The search for hard-rock kappa (I) in NGA-East: A semi-automated method for large, challenging datasets in stable continental regions by Olga-Joan Ktenidou, Norman A Abrahamson, Walter J Silva, Robert B Darragh and Tadahiro Kishida

   *Release Date: July 13, 2021. https://doi.org/10.1177/87552930211019763*

6. Selection of random vibration theory procedures for the NGA-East project and ground-motion modeling by Albert R Kottke, Norman A Abrahamson, David M Boore, Yousef Bozorgnia, Christine A Goulet, Justin Hollenback, Tadahiro Kishida, Olga-Joan Ktenidou, Ellen M Rathje, Walter J. Silva, Eric M Thompson and Xiaoyue Wang

   *Release Date: July 13, 2021. https://doi.org/10.1177/87552930211019052*

7. A ground-motion prediction model for small-to-moderate induced earthquakes for Central and Eastern United States by Zoya Farajpour and Shahram Pezeshk

   *Release Date: June 6, 2021. https://doi.org/10.1177/87552930211016014*

8. Regional attenuation models in Central and Eastern North America using the NGA-East database by Jeff Bayless

   *Release Date: June 15, 2021. https://doi.org/10.1177/87552930211018704*

9. Multi-method site characterization to verify the hard rock (Site Class A) assumption at 25 seismograph stations across Eastern Canada by Sameer Ladak, Sheri Molnar and Samantha Palmer

   *Release Date: April 9, 2021. https://doi.org/10.1177/87552930211001076*

10. Application of empirical and simulation-based site amplification models for Central and Eastern North America to selected sites by Youssef MA Hashash, Okan Ilhan, Halil Uysal, Jonathan P Stewart, Sissy Nikolaou, Ellen M Rathje, Kenneth W Campbell and Walter J Silva

    *Release Date: June 18, 2021. https://doi.org/10.1177/87552930211020770*

11. Scaling relations between seismic moment and rupture area of earthquakes in stable continental regions by Paul Somerville

    *Release Date: February 7, 2021. https://doi.org/10.1177/8755293020988024*

12. Simplified methods to estimate mean hazard due to updated ground motion model: Application to nuclear power plants in CEUS by Mohamed M Talaat, Andrew Seifried, Abhinav Anup, Gregory S Hardy and John M Richards

    *Release Date: May 7, 2021. https://doi.org/10.1177/87552930211007499*

13. Seismic risk assessment for the CEUS nuclear power plant fleet based on the NGA-East ground motion model by Mohamed M Talaat, Timothy J Graf, Abhinav Anup, Gregory S Hardy and John M Richards

    *Release Date: July 7, 2021. https://doi.org/10.1177/87552930211024681*

14. Site effects of the Denis-Perron dam (SM-3): A case study in Eastern North America by Daniel Verret, Denis LeBœuf and Éric Péloquin

    *Release Date: June 11, 2021. https://doi.org/10.1177/87552930211019439*

15. System-wide seismic vulnerability of aging multiple-span multiple-girder bridges in low-to-moderate seismic hazard regions by John E Lens, Mandar M Dewoolkar and Eric M Hernandez

    *Release Date: July 13, 2021. https://doi.org/10.1177/887552930211021434*

16. Data analytics to investigate the cohort of injection wells with earthquakes in Oklahoma by Amin Amirlatifi, Bijay KC, Meisam Adibifard, Farshid Vahedifard and Ehsan Ghazanfari

    *Release Date: February 8, 2021. https://doi.org/10.1177/8755293021989725*

Dissemination

The final release of the full collection of papers in the Special Issue was advertised widely through various EERI and PEER communication channels, along with announcements to several partner organizations and outreach to various research groups familiar with NGA-East. Additionally it was advertised to more than 200 university and research libraries with

subscription access to *Earthquake Spectra* as well as the broader SAGE readership via posts on its Engineering Hub.

Impact

In learning about and understanding the database, methodology and models of the NGA-East project, through the *Earthquake Spectra* special issue, researchers and practitioners will be able to conduct improved probabilistic seismic hazard analyses in the CENA region. This is especially important for the end-users of the USGS National Seismic Hazard Models, as well as for the entire nuclear power plant industry with about 100 nuclear power plants located in CENA. The journal format allows the results of the transformational NGA-East project and related studies to be more easily digested by the NEHRP community than other exhaustive project technical reports already produced.

## Project Data

No scientific data was collected or produced through this grant.

The papers in the Special Issue are available on the *Earthquake Spectra* website. A full pdf of the entire special issue has also been prepared and provided to USGS. This version of the publication has been provided with the understanding that the United States Government is authorized to reproduce and distribute reprints for Governmental purposes.

## Bibliography


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2. EERI. “EERI Releases Earthquake Spectra Special Issue On Seismic Hazard In Central And Eastern North America.” EERI Website, 2021. https://www.eeri.org/about-eeri/news/9217-eeri-releases-earthquake-spectra-special-issue-on-seismic-hazard-in-central-and-eastern-north-america
3. EERI. “Earthquake Spectra Call for Papers on CENA Special Issue.” EERI Website, 2020. https://www.eeri.org/about-eeri/news/4236-55earthquake-spectra-call-for-papers-on-cena-special-issue


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## Disclaimer

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